Study on the Structure of Bionic Damping Plate of Belt Conveyor

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Abstract

According to the application of belt conveyer antiskid device damping plate, considering the influence of the damping plate structures on the braking effect. Through the theoretical analysis, the formula of the friction characteristics of the damping plate is obtained, and the factors affecting the friction coefficient of the damping plate are obtained from the formula. Using the bionic "flexible interlocking" principle and combining with practical application, the structure of the bionic rubber-coated damping plate is designed to improve the braking performance of the damping plate.

Keywords

Conveyor belt; Bionics; Friction characteristics; Damping plate.

1. Introduction

Belt conveyor plays an irreplaceable role in the process of material transportation. However, in the process of using conveyor with large inclination and long distance, the conveyor belt often breaks or reverses due to the gravity of materials, causing serious losses to the development of mine resources. To avoid such accidents, many major coal mines have taken a lot of protective measures, such as the use of one-way roller and arresting device, but these protective measures are relatively high cost and short life. It is a new idea to install the damping plate under the conveyor belt. When the conveyor belt breaks and reverses, the conveyor belt tension drops rapidly and comes in contact with the damping plate, which effectively prevents the conveyor belt from slipping when the friction generated between the damping plate and the belt is large enough.

2. Overview of bionics

Bionics is a science that mimics the special ability of organisms and uses the structure and functional principles of biology to develop machinery or a variety of new technologies.

Bionic design is a new research and design method that simulates and designs biological performance characteristics by studying various biological forms, structures, functions and other factors. It is a multi-disciplinary frontier subject, involving a wide range of research and rich content. The general principle of the operation of bionics, as shown in Figure 1.

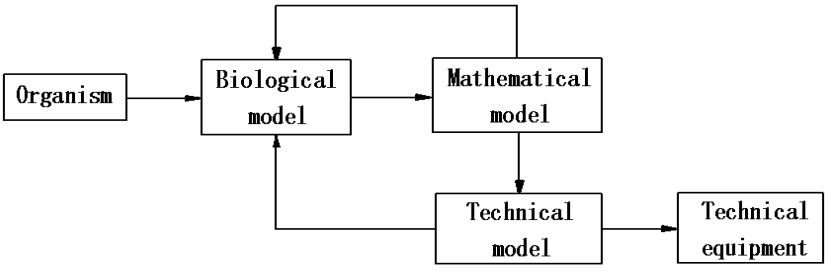

Fig1 Principle of bionics

3. Analysis of friction characteristics on the surface of damping plate

Coulomb's law model:

$$\sigma_{fr} \leq -\mu\sigma_n t \tag{1}$$

In the formula, σfr is frictional stress, σn is normal stress at the contact node, μ is the coefficient of friction and T is the tangential unit vector in the direction of relative sliding velocity. In order to the stability of finite element, an inverse tangent correction formula of Coulomb's law is established as

$$\sigma_{fr} \leq -\mu \cdot \sigma_n \cdot t \cdot \frac{2}{\pi} \arctan\left(\frac{v_t}{r_v}\right) \tag{2}$$

The rv is the critical value of the relative velocity between two contact objects.

Based on Coulomb friction model, the friction model of damping plate is deduced. The friction coefficient is regarded as the objective function, and the relative sliding speed, surface roughness, deformation, temperature and macro surface structure are taken as variables of the objective function, and the equation is established as

$$\mu=\mu(v,\rho,\varsigma,m) \tag{3}$$

1) Velocity: Through experimental analysis, it can be found that the change of friction coefficient caused by the speed can be calculated by the formula (4).

$$\mu_v = (a+bU)e^{-cU} + d \tag{4}$$

The U are the speed, and the other coefficients are determined by the load and the material.

2) Roughness:

$$\mu_p = \mu(\rho) \tag{5}$$

The ρ is related to the three height parameters of the surface roughness.

3) Deformation: Deformation satisfy Formula（6）.

$$\mu_\varsigma = \mu(\varsigma) = m_1 + m_2\varsigma + m_3\varsigma^2 \tag{6}$$

The m1, m2 and m3 are deformation coefficient.

4) Temperature component: the temperature in actual operation should not be ignored. The effect of friction coefficient can be calculated by the formula (7).

$$\mu_T = \mu(T) = n_1 + n_2T + n_3T^2 \tag{7}$$

The n_1, n_2, and n_3 are temperature curve coefficient.

5) Macro surface structure: the surface structure of the special shape of the damping plate will affect the friction coefficient, which is calculated by the formula (8).

$$\mu_m = \mu(m) \tag{8}$$

The m is related to the surface structure of the damping plate.

The above factors are integrated to calculate the friction coefficient formula (9) of damping plate.

$$\mu = w_1\mu_v + w_2\mu_\rho + w_3\mu_\varsigma + w_4\mu_T + w_5\mu_m \tag{9}$$

The above formulas are calculated and the friction model function of the damping plate is deduced.

$$\begin{aligned}\sigma_{fr} &= \mu(v,\rho,\varsigma,m)\sigma_n \\ &= (w_1\mu_v + w_2\mu_\rho + w_3\mu_\varsigma + w_4\mu_T + w_5\mu_m)\sigma_n \\ &= -w_1\left[(a+bU)e^{-cU} + d\right]\sigma_n + w_2\mu(\rho)\sigma_n + w_3(m_1 + m_2\varsigma + m_3\varsigma^2)\sigma_n \\ &\quad + w_4(n_1 + n_2T + n_3T^2)\sigma_n + w_5\mu(m)\sigma_n\end{aligned} \tag{10}$$

4. Study on the structure of bionic damping plate

4.1 Influencing factors and coping methods

By analyzing the friction characteristics of the damping plate, increasing the area of contact between the damping plate and the conveyor belt can increase the sliding friction directly between the two, which is also a direct factor affecting the friction force. Therefore, the choice of the appropriate size, that is, can play the role of braking and can also reduce the cost.

It can be seen from the derived friction coefficient formula that the friction coefficient has an important influence on the friction force, and also determines the motion state when the conveyor belt breaks and reverses. Therefore, it is very important to study and analyze the size of the friction coefficient and the influencing factors.

In order to enhance the antiskid effect of the damping plate and increase the friction between the conveyer belt and the damping plate, the following improvement methods are proposed.

Designs a reasonable shape of the damping plate. The main shape of the damping plate is a flat plate, which can only contact a part of the conveyor belt. The shape of the damping plate is designed as a groove structure, so that the damping plate is fully contacted with the conveyor belt, and increase the contact area between the damping plate and the conveyor belt, so as to achieve the purpose of increasing the friction force.

Adhesive design on the surface of B. damping plate. The shape of the adhesive surface of the damping plate is optimized by the bionic technology, improving the friction coefficient on the surface of the damping plate and increasing the friction force on the contact surface.

4.2 Overall shape design of damping plate

The load ratio of each section of the damping plate is assigned by the load analysis of the reference slot roller. The load in the middle section is maximum, which is calculated by 70% of the weight of the material and 40% of the weight of the conveyer belt.

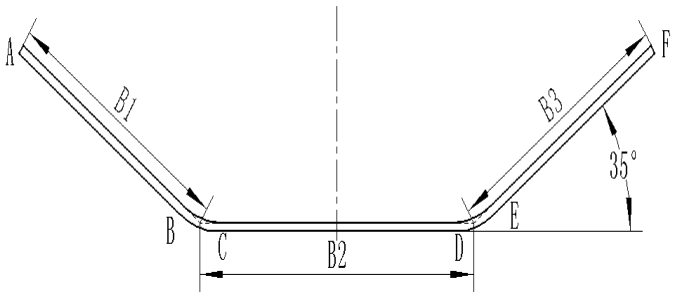

Fig 2 Side view of damping plate

As shown in Figure 2, the groove damping plate is composed of flat plate segments AB, CD, EF and two blocks of arc section BC and DE. The length of the side plate is B1 and B3, and the length of the middle plate is B2. Considering that the groove angle of most of the groove supporting rollers is 35 degrees, the groove angle of the groove damping plate is also designed to be 35 degrees, and the radius of the arc section of the damping plate is equal to the radius of the bending arc segment formed by the conveying belt through the groove supporting roller group.

By establishing the same roller group experimental platform, the state of the conveyor belt full load parking is simulated, and the length of each side of the conveyor belt is measured. The average length of the B2 is 504mm. The length of the side plate of the damping plate meets the following formula:

$$B1+B2+B3 \geq B,\ B1 = B3 \tag{11}$$

The conveyor belt bandwidth of 1300mm, B1 and B3 meets the formula is 2B1≥B-B2, by calculating the side length of more than 348mm. There is the deviation of the conveyer belt running, braking parts of conveyor belt are offset, in order to prevent the offset of the conveyor belt can fully contact

with the damping plate, side length of 100mm as the band offset compensation amount, the side length is B1=B3=448mm and the plate thickness is h=0.006m, the material is Q235 steel structure. The damping plate is a piece of steel plate, and the arc section is treated by bending, which avoids the problems of welding deformation and strength shortage.

4.3 Bionic surface design of damping plate

The foot pad of locusts is hexagonal. When contacting with external objects, the hexagonal flexible surface can expand the contact area, copy the contours of the contours and produce interlocking phenomenon, as shown in Figure 3.

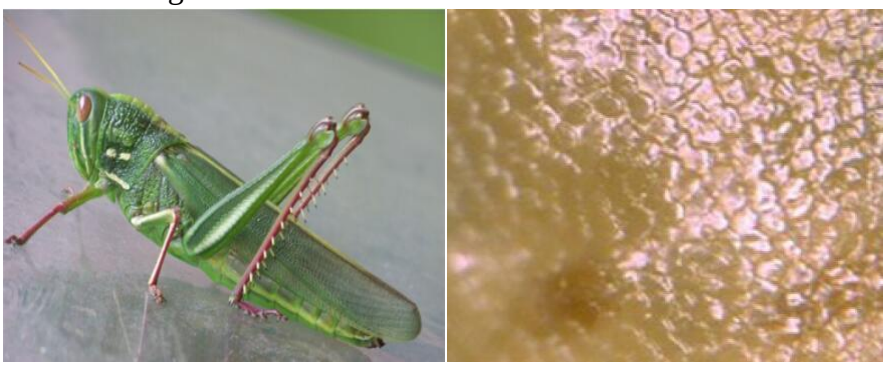

Fig3 Characteristics of the locusts' foot pad

By observing and analyzing the characteristics of the non smooth foot pad of the locusts, there is a flexible interlocking phenomenon in contact with the object. The function of flexible interlocking is mainly embodied in the winding or embedding between the convex hull and the interface, as shown in Figure 4. The convex hull of the interface can fill a dent on another contact surface. Because of the softness of the biological tissue, the pads can temporarily copy the outline of the interface. According to different surface roughness, smaller roughness area can be embedded in the larger roughness area, so the interface can produce redundant friction.

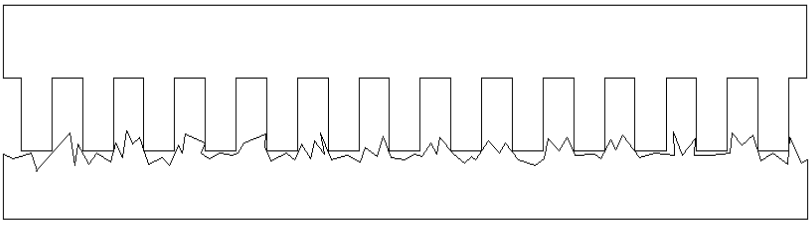

Fig4 Flexible interlocking phenomenon

Use this idea to design the bionic diamond mesh hull damping plate structure (Figure 5), the dark blue part is a damping plate, and the gray brown part is the adhesive layer. The material of the damping plate is Q235 and the adhesive material is a common rubber with a certain hardness.

When the damping plate is in contact with the conveyor belt, the conveyor belt is closely attached to the outer surface of the adhesive under the action of tension. Due to the difference between the adhesive and the material with the belt, there is a certain hardness difference, the convex hull will press the conveyor belt tight, and the contact area will produce a sag. At this time, the convex hull is pressed into the inner surface of the conveyor belt. This phenomenon is a kind of "flexible interlocking" effect, which will improve the contact state between the belt and the rubber damping plate, and increase the friction between them. The contact form of the damping plate and the conveyor belt is changed from the plane contact to the meshing contact, which greatly increase the friction between the damping plate and the conveyor belt.

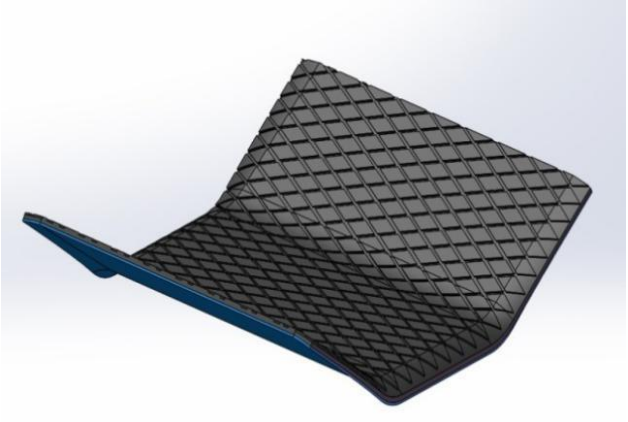

Fig5 Rubber linings of damping plate

5. Summary

The friction characteristics of the conveyer belt and the damping plate are analyzed, and the factors affecting the friction characteristics are obtained. According to the influential factors and the principle of biomimetic antifriction, the structure of the damping plate is optimized and the bionic adhesive damping plate with the best effect is designed.

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